VIRGINIA COASTAL RESOURCES MANAGEMENT PROGRAM

Memorandum of Agreement - 50312-01-13-PT

Title of Project:	**Impact of Onsite Wastewater Systems on Water Quality in Coastal Regions**
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Executive Summary:

This project evaluated the use of a fluorometer in estuarine and coastal zone environments to determine if the equipment could detect a human waste signature. The fluorometer detects compounds that fluoresce under ultraviolet light such as fecal sterols, detergent surfactants and optical brighteners. Optical brighteners in laundry and dishwashing detergents fluoresce when exposed to certain ultraviolet wavelengths, so water samples that fluoresce under those same wavelengths are contaminated by residues from laundry and dishwashing detergents (human sources). There are at least two major potential human sources of contamination that could contain optical brighteners, and these include leachates from improperly functioning on-site wastewater systems (OWS) and leaking pipes from community wastewater treatment systems. In rural areas where the majority of homes are served by on-site systems, optical brighteners in water samples indicate failing conditions within OWS in close proximity to the sampled bodies of water.

The fluorometer that was initially evaluated was ineffective. There were problems with the instrument electronics and, in addition, the instrument was deemed unsuitable for our use based on the results obtained with it. A detector from a different manufacturer was evaluated (Turner Industries) and it performed well in both laboratory and field tests. The detector located fluorescent plumes in water samples taken in coastal rivers where a human signature was known to exist based on microbial source-tracking results. Additionally, the detector correctly identified samples in controlled laboratory tests that had been spiked with detergents and/or septage. Samples without septage or detergents (or containing detergents without optical brighteners) all failed to fluoresce. The instrument was then used successfully on a variety of waterways (both salt and fresh) where human sources of pollution were suspected or could be confirmed with microbial source tracking technology. In larger bodies of water, fluorescent plumes could be identified and mapped with the fluorometer, and then traced back to the shore and directly to locations that appeared to be the source of the pollution. The fluorescent signals appeared to be stable over seasons, storage in refrigeration for at least four months, and over different water conditions. Whenever fluorescent plumes were found, microbial source tracking tests demonstrated a human signature in every case where source tracking was performed.

Project Background:

There is great demand for waterfront development in Virginia and other coastal states. Along with the development, questions have arisen regarding the potential for these waters to be contaminated with biological and chemical contaminants from OWS that most development in Virginia's coastal areas will rely upon. Much of the existing research literature on OWS indicates that, with 46cm of unsaturated soil depth between the area where septic tank effluent (STE) is applied and the water table, a minimum 15m separation distance to streams, lakes, and impounded waters, and 21m to shellfish waters, there should be little potential for biological contamination of these waters. When considering the above information, a recent study conducted in Indiana (unpublished, by William F. Grant, personal communication, 02/00) indicated that leachate plumes from septic systems were identified in all of 30 lakes tested. The plumes were identified with a leachate detector that responded to optical brighteners present in water. Finding plumes in all lakes tested was a major surprise, and served as the justification for the project results described in this report. The goal of the project was to conduct studies on coastal zone waterways to determine if fluorescent contaminant plumes entering the waterways could be reliably detected. Project objectives involved sampling and testing all identified fluorescent plumes for fecal coliforms and chemical contaminants such as nitrate and phosphate. For those plumes where fecal coliforms were also found, source-tracking technology was used to determine if these coliforms were human or non-human in origin.

Significance of the Research Problem:

Due to rapid development of waterfront property in most coastal areas of Virginia, an important issue has emerged regarding the contribution of biological and chemical contaminants to Virginia's coastal zone waters from individual OWS and mass subsurface absorption systems. Virginia's population is approximately 6.2 million people, with roughly one-third reside in households served by an OWS (one-fourth on households in the U.S. are served by an OWS). Approximately 360 million liters of wastewater are applied daily and 128 billion liters annually to Virginia soils by OWS. In many coastal counties in Virginia almost all of the population is served by an OWS, which makes the possible contamination of water bodies by leachates from OWS an issue of major concern. Research on such contributions has been difficult because there has been no reliable methodology that could identify potential sites of human-derived contamination. However, recent research (unpublished, by William F. Grant, personnel communication, 02/00) indicates that STE is being discharged into the near-shore areas of 30 Indiana lakes through subsurface discharge of STE plumes. He also reported that these plumes were independent of soil type and depth to the water table. These invisible STE plumes were identified using a leachate detector that detects fluorescent optical brighteners in laundry and dishwashing detergents. Plumes identified by Grant were tested for fecal coliform and ortho-phosphate and appeared to confirm the leachate detector results, however Grant's study did not attempt to determine the sources of the fecal organisms associated with contaminant plumes.

The results from Grant's study do not agree with OWS research that has been conducted in Virginia over the past 20 years (Duncan et al., 1994), or that has been conducted at other locations which indicated that the migration distance of biological contaminants is directly related to soil properties and depth to a watertable (Brown et al., 1979; Green and Cliver, 1975; Hagedorn et al., 1981; Reneau et al., 1989; Romero, 1970; Yates et al., 1986; and Ziebell et al., 1974). Most of the studies that show biological contaminants traveling extended distances were conducted in saturated coarse textured soils or in soils that had very large continuous pores

(Hagedorn et al., 1981; Reneau et al., 1989; Romero, 1970; and Yates et al., 1986). Virginia Department of Health regulations (VDH, 1989) were designed to reduce the potential for environmental degradation from OWS. Since it is not obvious that the problem found in Indiana lakes is present in Virginia's coastal waterways, the current study was conducted to determine if STE plumes could be identified in near-shore waters adjacent to housing developments that utilize OWS, by comparing developed sites that have a high potential for contamination to sites with similar landscape features and soil types that have not been developed (control sites). The types of OWS located at the lakes where Grant conducted his study have not been identified, and it is possible they include systems that encourage transport of pollutants in concentrated plumes. Another possibility is that the soils in Grant's study were both shallow and permeable, which encouraged pollutant migration away from the OWS, and finally, the instrument used by Grant may have been detecting fluorescent compounds that were not human in origin.

Research Progress:

1. Fluorometer (Kerfoot Industries, Mashpee, Ma):

The leachate detector that was initially evaluated was the instrument used in Grant's study (unpublished, by William F. Grant, personnel communication, 02/00). It is an instrument that scans samples over a non-variable range of wavelengths. We were not able to use this instrument in the field with any success. There appeared to be problems with the instrument electronics on both occasions when this instrument was taken to the field. The instrument was also bulky, was not adequately insulated against static interference, and may not have been best suited for measurements in the marine environment.

2. Fluorometer (Turner Industries, Sunnyvale, Ca):

The Turner Designs Ltd. Model 10-AU-005 Field Fluorometer (Images 1 and 3) was used successfully in our study. The instrument configuration was the same as that used by Petch (1996), and the fluorometer was set up to detect long wavelength oils and optical brighteners at Turner Designs, Ltd. For field use, water is continually pumped through the leachate detector with a submersible pump and results from a digital readout are obtained immediately (Image 3). The fluorometer is a portable piece of equipment that can be used from a boat to sample a large number of sites in a reasonable time. For lab use, the continuous flow system is removed and a cuvette system is added to accommodate discrete samples of 10 ml or less).

The digital readout (can be used with a recorder) ranges from –999 to +999, and for field use the approach was to calibrate the instrument as close to zero as possible with a water sample that was from the same body of water (river, stream, etc.) that was being evaluated at that time, and was from an area that was thought not to contain any human-derived pollution. Calibration of samples for laboratory use was done in the same manner; deionized water was used as a negative sample while positive samples consisted of water to which small amounts of detergent were added (0.264 mL of Food Lion Clean Detergent with Bleach Alternative (liquid) added to 200 mL of tap water for a standard of 0.132% detergent). Once the instrument was calibrated to near zero, deionized water produced strong negative readings and 10 to 20 mL of the detergent standard added to 1.0 L of tap water produced strong positive readings. Precise dilutions of the detergent or effluent from an experimental OWS provided positive readings that were almost linear over the concentration ranges studied (Figures 1 and 2). Prior to field evaluation, the instrument was tested successfully with several different types of samples. Waters that were suspected not to have pollution from human sources (springs from a variety of rural locations and streams from remote areas of the Jefferson National Forest) did not fluoresce. Waters with obvious pollution sources from wildlife or livestock (but not human) did not fluoresce. A commercial detergent that was advertised as containing no optical brighteners did not fluoresce, and samples from different wastewater treatment plants and on-site systems all fluoresced.

Two important lessons were learned from laboratory tests: first, the optical brightener "signature" survived both municipal and domestic wastewater treatment systems and could be detected at very dilute levels; second, the fluorometer could be accurately calibrated and concentrations of fluorescent compounds yielded a linear response. Based on the lab results, the fluorometer was deemed ready for field-testing.

3. Sampling Locations: Coan River and Little Wicomico River (Northumberland County, Va).

In 2002 a bacterial source-tracking project was performed on the Coan River and Little Wicomico River as part of the Virginia Department of Environmental Quality (DEQ) Shellfish TMDL program. Most shellfish beds in both rivers are closed to harvest due to high fecal coliform numbers, and one year of source tracking demonstrated that a dominant human signature was present in both rivers (Table 1 – summary for Coan River). Based on the source tracking results from the DEQ project, these two rivers with a high human signature were obvious locations to field test the fluorometer. Water samples were collected from both Rivers at various times over the remainder of the project. Shoreline samples were collected from areas with developed shorelines (older homes, Image 4), local marinas served by pit privies (Image 5), areas with less dense housing (new homes), natural areas with no homes, and agricultural areas that comprised less desirable habitats for wildlife. Fecal bacteria were isolated from the water samples and source-tracking technology was employed to fingerprint the fecal bacteria and determine if they were human or non-human in origin. The samples were collected by slowly cruising along shorelines in boats provided and piloted by personnel from the VDH Division of Shellfish Sanitation (DSS, image 2), and a smaller boat was used to move slowly along shorelines and run the fluorometer and collect samples from areas of interest (Image 3).

The first field test was on the Coan River in October 2002, and results were inconclusive (Table 2). The two background samples (#s 1 and 10) were in the same range as all of the other readings. However, this first sampling was done on the high tide and, in hindsight, this was not the best time to sample since high tidal waters would, to a large extent, block the movement of OWS contaminant plumes to the river. In addition, in blanking the instrument with water from the river, it is important to use water that does not contain a substantial fluorescent signature. Such water for blanking may be hard to find in areas such as the Coan River, since the DEQ project results demonstrated that a human signature was widely dispersed in the Coan River. Lastly, the fluorometer needed to be tested at a wider range of developed and undeveloped locations so that differences could be seen by comparison (rather than concentrating on just the older homes). Fecal coliforms were present in almost all of the samples, and it was apparent that fecal coliforms alone offered little information to help determine the source of the pollution. Bacterial source tracking was performed on four samples but the presence of a human signature was not clearly related to the fluorometer results.

The second field test on the Coan River was performed in April 2003, and the results were very positive (Table 3). The field test was done on the outgoing tide, and the instrument was calibrated in the middle of the river channel, resulting in background levels of +3 to +9 to –5 (samples 2 and 17, Table 3). Samples from newer homes and undeveloped areas showed no fluorescence (samples 3, 10-12, and 16), while samples from near-bulkhead locations around older homes and samples from a cove with homes of different ages, a small marina, and a pit privy all demonstrated fluorescence (see samples 4-9). The presence of the contaminants appeared to come from a single house located in the cove, and the pit privy did not appear to be the source of the contaminant plume at the time the samples were collected. The fluorescence from the older homes was repeatable as high positive readings were obtained by returning to the same area (samples 13 and 14). The cove results were repeatable as well (sample 17), and the plume could be followed to one specific home where suds were visible on the water. All samples were positive for fecal coliforms. Bacterial source tracking was performed on eight of the samples and the results agreed with those from the fluorometer (Table 3). No human signature was found with five samples where there was no fluorescence, and a human signature was found for three samples that demonstrated fluorescence. The lessons from this field test were that bacterial source tracking agreed with the fluorometer, the instrument needed to be tested on the outgoing tide (for tidal waters), and fluorescent plumes, once found, could readily be found on repeated attempts, and the plumes could be followed to the locations they originated from.

The first field test on the Little Wicomico River was performed in June 2003 and the results were encouraging (Table 4). The field test had to be stopped early due to thunderstorms. The samples were collected and the instrument tested on the outgoing tide, and the fluorometer was calibrated in the middle of the river channel, resulting in background levels of –20 to +50 (sample 1, Table 4). Areas along the shore that were fully developed with homes of different ages, docks, and a wide variety of boats all yielded substantial fluorescent signals (samples 2 to 8). Due to storms, there was not time to visit many other locations, but two undeveloped areas did not fluoresce (samples 9 and 10), confirming the results from the second trip on the Coan River (Table 3). All samples were positive for fecal coliforms. Bacterial source tracking was performed on three of the samples and the results agreed with those from the fluorometer (Table 4). No human signature was found with one sample where there was little fluorescence, and a human signature was found for two samples that demonstrated fluorescence. Substantial algal growth was present at all locations and caused some instability in the fluorometer, as the readings for the calibration varied from –20 to +50. Background values did not play a large role in the identification of fluorescence since relative changes above background are detected as positive readings after calibration. However, the readings were more variable than on previous trips (Coan River), so there was less confidence that sources of contaminants could be located on that day, unless the fluorescent readings were very high. The background variability may have been caused by fluorescent compounds produced by marine algae, or simply the presence of algae partially clogging the flow cell, but no experiments were preformed to determine this.

The Turner instrument worked successfully in its first field trials in coastal waters in Virginia, and appears to be a promising approach to leachate plume detection. For the Coan and Little Wicomico Rivers, near-shore waters from areas with older homes continue to demonstrate strong fluorescent plumes indicative of optical brighteners from detergents, while areas with newer homes and natural areas with no homes did not. One issue with using a fluorometer in marine waters has been the production of fluorescent pigments by photosynthetic algae during the summer months. Considerable blooms of algae were present in the Coan and Little Wicomico Rivers in June of 2003, and some type of natural fluorescence did register (but all readings were below +100). While this fluorescence is most likely from marine algae, it was not proven that this was the case. Although the instrument readings were more erratic, the level of fluorescence was still well below that found in plumes adjacent to older home areas (+200 to

>+300).

4. Sampling Locations: Piankatank River (Gloucester County, Va).

A field test on the Piankatank River was performed in March 2003, and the results were encouraging (Table 5). The field test was done on the outgoing tide, and the instrument was calibrated in the middle of the river channel, resulting in background levels of zero to 6.5 to -13 (samples 1 and 14, Table 5). Samples from newer homes and undeveloped areas showed no fluorescence above background (samples 2-5, 7, and 11-15), while samples from near-shore locations around older homes and samples from a cove with older homes, and one served by a drainage ditch all demonstrated fluorescence (see samples 6, 8, and 9-10). All samples were positive for fecal coliforms. Bacterial source tracking was performed on seven of the samples and the results agreed with those from the fluorometer (Table 5). No human signature was found with five samples where there was no fluorescence (samples 2, 8, 11, 12, and 13), and a human signature was found for two samples that demonstrated fluorescence (samples 6 and 9). However, it is important to realize that fluorescent readings are relative and it is not appropriate at this time to imply that lower readings indicate that a body of water is less contaminated. It is obvious from our results on the Coan, Little Wicomico, and Piankatank that different rivers have different levels of background fluorescence that may or may not be related to the amount of contamination present. Natural organic compounds that fluoresce could also be present and may not be directly related to the relative level of contamination present at any one time.

5. Water Chemistry and Fluorometer Results.

Tables 9, 10, and 11 contain the tabulated water chemistry results (Nitrate, Ammonia, Phosphate, and Total Suspended Solids) for the Coan River in April 2003 (Table 9), the Little Wicomico River in June 2003 (Table 10), and the Piankatank River in March 2003 (Table 11). None of the water chemistry results indicated a water quality problem with any of the measured parameters and all values were within acceptable levels for good water quality. There was also no apparent connection between water chemistry values and the fluorometer readings. Since all of the water quality values were low, there were no high readings that corresponded to high fluorometer values at any of the sites where water chemistry was performed.

6. Sampling Locations: Huntington Beach, Ca.

As part of a separate source-tracking project funded by the Southern Coastal California Water Research Project (SCCWRP) and the EPA, twenty-four water matrix samples (12 salt, 8 fresh, 4 humic acids) were sent to the Va Tech lab for testing. Seven of the samples had treated sewage added, and 4 of the 7 samples containing sewage were 100% sewage (by volume) while 2 samples had sewage added at 1%, and 1 sample had sewage added at 4% (Table 6). The samples were sent to VT in October of 2002, but were not tested with the fluorometer until February of 2003. Those to which sewage had been added demonstrated fluorescence and those without sewage did not, and there was a concentration difference as the 100% sewage samples had fluorometer readings of over +100 (Table 6). These results demonstrated that optical brightener signals from sewage lasted at least four months in samples stored under refrigeration, and the fluorometer could detect samples to which only 1% sewage had been added, and could differentiate between additions of small and large concentrations of sewage.

7. Sampling Locations: Washington, D.C. Area..

A separate source-tracking project was being performed on the Potomac River, Anacostia River, and Rock Creek under sponsorship of the Washington D.C. Council of Governments. Due to problems with combined sewer overflows, bacterial source tracking had demonstrated that human signatures were common in most of the samples that were collected monthly. There were numerous combined sewer overflows in February as a result of precipitation and snowmelt, and a distinct sewage odor was prevalent on the Anacostia River when the samples were collected. The February samples from all three water-bodies were examined with the fluorometer and all fluoresced (Table 7). The highest fluorometer readings occurred with the Anacostia samples and lower Rock Creek, but all samples were positive. The fluorometer results confirmed the human signature results obtained from bacterial source tracking, and demonstrated the utility of the fluorometer, where the presence (or absence) of a human signature could be obtained instantly, as compared to two weeks or more for bacterial source tracking results. Since there was no water sample from D.C. that had no fluorescent signal, it was necessary to use deionized water to calibrate the instrument (Table 7).

8. Sampling Locations: Prince William County, Va.

A new county-sponsored bacterial source-tracking project was initiated in July 2003, in Prince William County, Va. As this county is in the coastal zone, and the freshwater streams (all drain into the lower Potomac River) in the study are in undeveloped, agricultural, and suburban watersheds, it represented a good opportunity to test the fluorometer on samples collected for source tracking. The project started in July 2003, and the data in Table 8 are from the first set of samples collected. All samples were positive for fecal coliforms. The samples from Slate Run, a stream in an agricultural area with moderate housing density areas (all homes are served by on-site systems) contained a substantial fluorescent signal (Table 8, samples 4, 5, and 6). The stream in Prince William Forest (Quantico Creek, samples 1 and 2) is contained within an undeveloped area and had no fluorescence while Powell's Creek (a forested basin undergoing development) has a small fluorescent signal at one of two sites (sites 17 and 18). Sample 2 (reading of -0.8) was used to calibrate the fluorometer. Cedar Run, a large stream that originates in Fauquier County, had a small fluorescent signal as well (samples 3, 7, and 9). Neabsco Creek is a stream entirely contained in suburban sprawl around Dale City all of the development is served by sewers and wastewater treatment systems. All samples from upper Neabsco creek and tributaries had no signal (samples 10, 11, 12, and 14) while the two samples from the lower section of the creek (below a treatment plant outfall) had a small signal (Table 8, samples 13 and 16).

Fluorometer Applications:

The results from all of these field tests demonstrate that the Turner Industries fluorometer does have practical applications in locating specific sites where plumes from OWS were entering the rivers studied as part of this project. Using the type of fluorometer provided by Turner Industries will allow VDH to better implement the National Shellfish Sanitation Program in Virginia and provide an inexpensive field methodology for regional and local efforts to address impacts to water quality from human sources. As an agency with lead responsibilities under the Virginia Nonpoint Source Pollution Management Program, VDH will continue to address septic system issues within Virginia's coastal zone. Using a fluorometer to detect pollution form human sources will support implementation of 1) Coastal Chapter: Object 5 – "Reduce existing on-site sewage disposal systems impacts to water quality and prevent impacts from new systems," 2) Construction & Development Chapter: Objective 25 – "By the year 2005, develop mechanisms, framework and tracking systems in order to assess failing systems and actual pollutant loading," and 3) Construction & Development Chapter: Objective 26 – "By the year 2003, develop and present statewide OWS educational programs in cooperation with local governments." Application of the fluorometer will allow VDH to better identify the location of OWS impacts and implementation of corrective measures that result in the reduction of nutrients and fecal bacteria. Local health departments will be able to better target failing OWS and to initiate remedial actions. DCR will be able to better target NPS pollution program funds towards implementing appropriate BMPs, and DEQ can use the information to direct future monitoring efforts.

While source-tracking technology has met with great success in determining the sources of fecal contamination, it is not feasible to use this technology to identify specific sites that are the origin of human signatures. Fluorescence offers the potential for locating specific sites where fecal contaminants may be entering the water body under consideration. This should allow individual problem sites to be located and remediation to be performed. The use of fluorescence in such situations is potentially a low-cost way of reducing the human contribution to the pollution load in these waters.

The fluorometer will be very valuable as an aid in deciding where to sample on large bodies of water, especially lakes and coastal areas. The fluorometer can either be used in the field where water can be pumped through it via continuous flow, or set up for discrete samples (with a cuvette holder attached to the instrument). Large numbers of samples can be tested for fluorescence very quickly, and the results can be critical in deciding where the most appropriate places to concentrate sampling on large bodies of water are located. Due to lab costs and method difficulties, it is not feasible to analyze such large sample numbers with microbiology-based source tracking methods. The fluorometer should fill an important role in future source-tracking efforts in Virginia, as it can be used as a screen for human-derived sources. For those samples that contain no human sources of pollution, microbial source tracking can then be performed more economically and efficiently if only wildlife and livestock (or dog or bird) sources need to be identified.

Additional Research Needs:

While these results are very encouraging, additional lab and field work needs to be conducted to confirm these initial results, and expand them to other water bodies, both in and out of the coastal zone. Additional work to be completed involves evaluating different excitation wavelengths and determining how best to account for natural fluorescent compounds such as those produced by different species of marine algae. The best approach to this issue is to collect samples when algae are present, perform identifications of the algea where possible, and scan wavelengths to see where fluorescence occurs. Oil-based compounds from oil spills could also potentially contribute chemicals that could fluoresce and lab studies where oils can be added to water could be performed to examine this issue. Seasonality is another issue that should be resolved, as there may be particular times of the year when fluorescent signals are more prevalent and, if so, these times should be identified.

There appears to be justification for considering the soils associated with water bodies being studied for fluorescence. The Coan River, where we were most successful at identifying sources of fluorescence, was at a lower elevation and the soils are shallower than for the Little Wicomico River. There may also be an interaction between the age of the homes and the water table depth in the soils where the homes are located. We did not detect as many fluoreccent plumes around homes that were located on deeper soils. As fluorescence technology emerges as a source-tracking tool, it would be very valuable to study how well fluorescence is removed in soils over short distances when the soil is saturated or near saturation. Such information would be very helpful in making decisions regarding where to sample for fluorescence in water bodies, and how to interpret fluorescence after it has been found.

Acknowledgments

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DCR
Department of Conservation & Recreation
CONSERVING VIRGINIA'S NATURAL & RECREATIONAL RESOURCES

DEQ
VIRGINIA DEPARTMENT OF
ENVIRONMENTAL QUALITY
VIRGINIA COASTAL PROGRAM

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

The project investigators would like to thank the staff and management of the Virginia Division of Shellfish Sanitation, Virginia Department of Health, for providing boats, assistance, and resources during this project. Their willingness to accommodate our schedules and needs, and to take us out on the water in all types of weather to test the fluorometer is what made this project a success.

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Figure 1. Calibration of Turner Instruments fluorometer with recirculating media filter effluent from an experimental on-site wastewater treatment system.

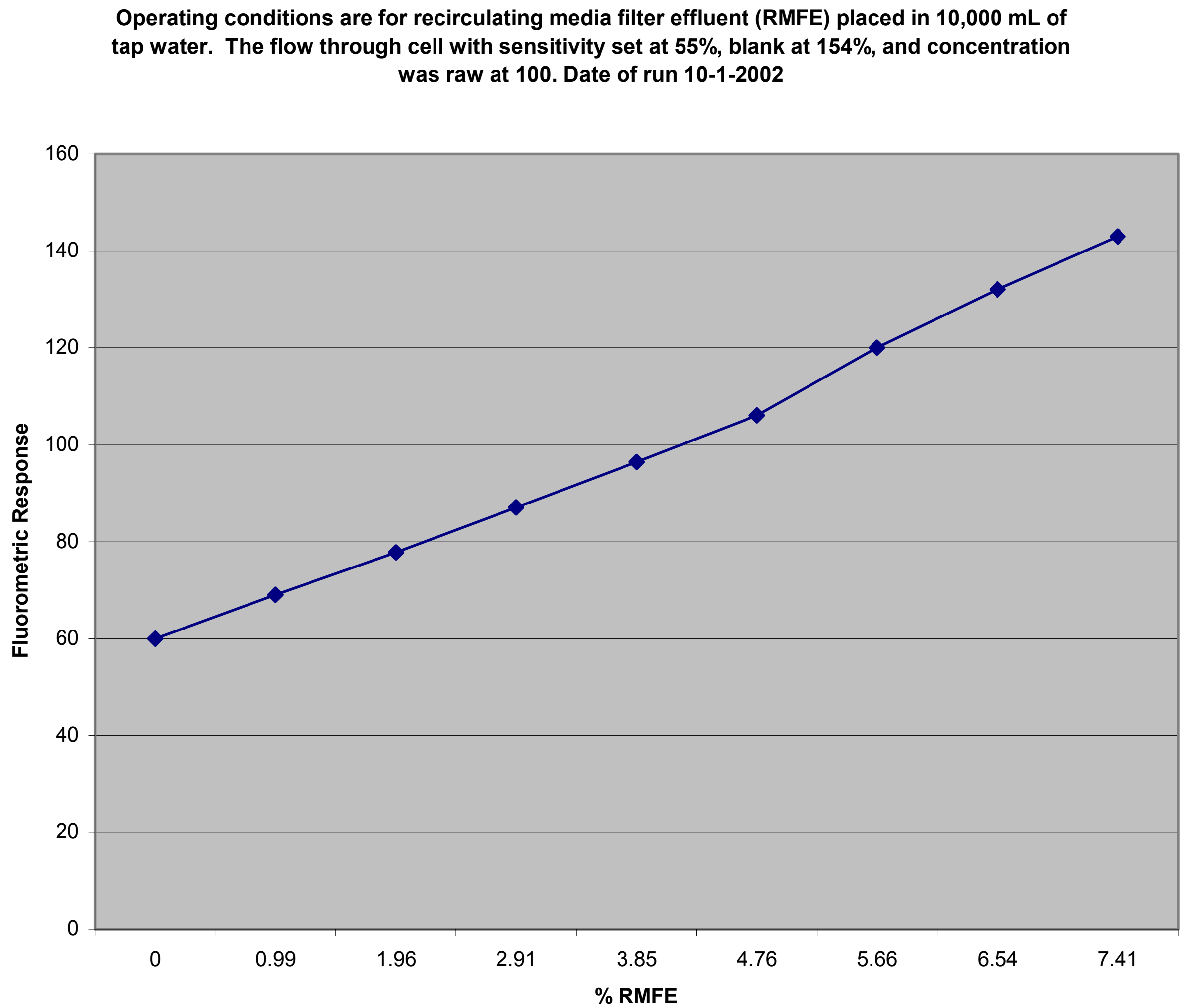

Figure 2. Calibration of Turner Instruments fluorometer with a commercial detergent.

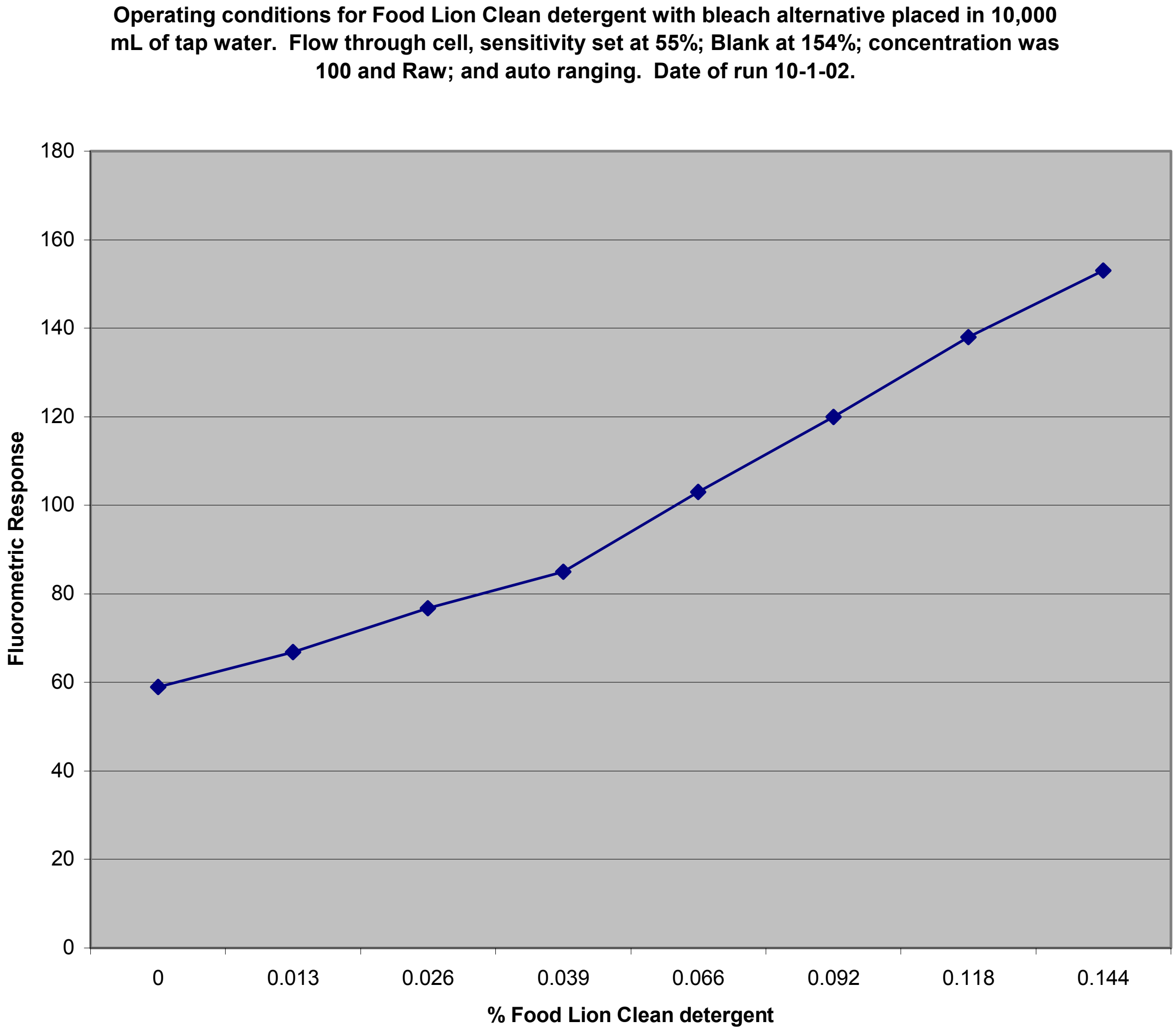

Table 1. Coan River Source Allocations and Unknown (No Match) Percentages of *E. coli* Isolates from Previous DEQ Project.

	AVERAGE CORRECT PERCENTAGES					
DSS STATION	BIRD	HUMAN	LIVESTOCK	PETS	WILDLIFE	UNKNOWN %
C-7	9.8	35.8	1.7	0.0	0.8	51.9
C-15	11.5	33.3	5.9	0.0	2.5	46.8
C-16	26.4	21.9	3.5	0.0	3.5	44.7
C-20	12.9	31.2	1.9	0.0	3.4	50.6
C-24	19.5	28.7	0.5	0.7	0.4	50.2
C-27	12.5	24.9	1.8	0.4	0.4	60.0
C-33	5.9	20.7	3.0	0.8	0.4	69.2
C-37.5Z	9.2	34.8	6.1	0.0	5.0	44.9
C-38	10.0	32.3	5.5	1.6	3.9	46.7

Table 2. October 2002 Sampling, Coan River.

Sample No.	Units of Fluorescence	Site Description	Presence-Absence for fecal coliforms	Human Signature
1	67	Background, calibration of instrument	Negative	---
2	76	Near dock, older homes	Positive	---
3	73	Bulkhead, older homes	Positive	---
4	72	Small beach, older homes	Positive	---
5	75	Gazebo area, older homes	Positive	---
6	83	Small marina, cove with privy	Positive	Yes
7	76	Long dock, older homes	Negative	No
8	79	Gray house, outbuildings, older homes	Positive	Yes
9	80	House with boat rack, older homes	Positive	Yes
10	75	Background	Negative	---

*--- indicates that bacterial source tracking was not performed.

Table 3. April 2003 Sampling, Coan River.

Sample No.	Units of Fluorescence	Site Description	Human Signature with Bacterial Source Tracking
1	16 to 75	Newer home	---
2	3-9	Background, calibration of instrument	---
3	–22 to –8	Vacant lot, no home	No
4	96 to 103	Older homes	No
5	84 to 130	Mouth of cove with privy	---
6	80 to 91	End of cove with privy	---
7	80 to 100	Homes in cove with privy	---
8	198	Homes in cove with privy	Yes
9	253	Homes in cove with privy	Yes
10	–145	New home near marina	---
11	–3 to 20	New home, house with TV tower	---
12	–120	Single newer home past marina, undeveloped	---
13	31 to 80	Return to older homes	---
14	95 to 217	Return to older homes	---
15	331	Shallow area near older homes	No
16	7	Undeveloped area	---
17		Details while cruising as follows:	
	-6 to –36	Undeveloped area	No
	-5	Recalibration in middle of river	No
	150	Mouth of privy cove	---
	243	In privy cove	Yes
	Over 300	House in privy cove, suds visible on water	---
	-5	Out of privy cove, recalibration	---

Table 4. June 2003 Sampling, Little Wicomico River.

Sample No.	Units of Fluorescence	Site Description	Human Signature with Bacterial Source Tracking
1	0	Background, calibration of instrument	---
2	300	Along bank, fully developed	Yes
3	200	Along bank, fully developed	---
4	300	Along bank, fully developed	---
5	80 to 100	Along bank, fully developed	---
6	300	Drainage way near older home	---
7	300	House without seawall	Yes
8	100 to 200	Sheltered cove, developed	---
9	50	Undeveloped wooded area	---
10	70	Undeveloped, algal bloom	No

Table 5. March 2003 Sampling, Piankatank River.

Sample No.	Units of Fluorescence	Site Description	Human Signature with Bacterial Source Tracking
1	6.5	Baseline, center channel	---
2	-11 to 7	Everetts Creek, older homes	No
3	4	Everetts Creek, older homes	---
4	10	Everetts Creek, older homes	---
5	-39	Long dock with birds, few homes	---
6	5 to 22	Drainage trench behind homes	Yes
7	-2 to -10	Homes away from shore	---
8	8 to 9	House behind island	No
9	16	Single house, possible sewage eruption	Yes
10	17 to 25	Same as #9, near island	---
11	–7 to -10	New homes near community area	No
12	–80 to -100	Dock with birds, new homes	No
13	-93 to -100	New homes, background sample	No
14	-13	Baseline, center channel	---
15	-95	Undeveloped area, marshy and wooded	---

Table 6. February 2003 Samples, Huntington Beach, Ca.

Sample No.	Units of Fluorescence	% Sewage Added to Sample in Ca.
A	**330**	**100**
B	8	0
C	-14	0
D	11	0
E	8	0
G	3	0
H	16	0
I	5	0
J	**70**	**1**
K	**140**	**100**
L	-2	0
M	4	0
N	**74**	**4**
O	12	0
P	-6	0
Q	**30**	**1**
R	**260**	**100**
S	-5	0
V	-5	0
W	**235**	**100**
X	7	0
Blank	-2	

Table 7. February 2003 Samples, Washington, D.C. Project.

Sample No.	Units of Fluorescence	Site Description	Human Signature with Bacterial Source Tracking
Blank	-21	Deionized water	---
1	175	Anacostia, DC/MD line	Yes
2	86	Anacostia, Bennig Rd.	Yes
3	143	Anacostia, Penn. Ave.	Yes
4	125	Anacostia, 11th St.	Yes
5	139	Anacostia, S. Capitol St.	Yes
6	122	Anacostia, Hains Pt.	Yes
7	75	Potomac, 3 Sisters	Yes
8	82	Potomac, Rock Creek	Yes
9	46	Potomac, Memorial Bridge	Yes
10	25	Rock Creek, DC/MD line	Yes
11	74	Rock Creek, Tilden St.	Yes
12	80	Rock Creek, Porter St.	Yes
13	93	Rock Creek, National Zoo	Yes
14	113	Rock Creek, Mass. Ave.	Yes
15	105	Rock Creek, Penn. Ave.	Yes

Table 8. Source Tracking Project, Prince William County, Fluorometer Values (July 2003)

Sample Location	Units of Fluorescence
1. Quantico Creek, Main Stem	-140
2. Quantico Creek, So. Fork (Blank)	-0.8
3. Cedar Run, Aden Rd.	110
4. Slate Run, Rt. 654	166
5. Slate Run, Fleetwood Dr.	202
6. Slate Run, Old Church Rd.	400
7. Cedar Run, Bristow Rd.	106
8. Cedar Run, Carriage Ford Rd.	no sample taken
9. Cedar Run, Fleetwood Dr.	80.6
10. Neabsco Creek, Delaney Rd.	-19
11. Neabsco Creek, Trib. Minnieville Elem. School	-54
12. Neabsco Creek, Lindendale Rd.	-60
13. Neabsco Creek, Benita Fitzgerald Rd.	77.6
14. Neabsco Creek, Trib. Cloverdale Rd.	-57
15. Cow Branch, Rippon Landing Park	-269
16. Neabsco Creek, Rt. 1	78.7
17. Powell's Creek, lower. Rt.1	-15
18. Powell's Creek, upper. Spriggs Rd.	79.6
19. Control, Deionized water	-540

Table 9. Coan River, April 2003, Phosphate, Total Suspended Solids (TSS), Nitrate, and Ammonium.

Sample ID	Phosphate (mg/L)	TSS (mg/L)	Nitrate (mg/L)	Ammonium (mg/L)
Coan 1	0.003	25.25	0.592392	0.19469
Coan 2	0.003	12.75	0.61511	0.182554
Coan 3	0.003	21.25	0.673084	0.085042
Coan 4	0.003	9.75	0.746941	0.098279
Coan 5	0.005	6.5	0.588048	0.246028
Coan 6	0.008	6.75	0.586943	0.23244
Coan 7	0.005	21.75	0.587266	0.228365
Coan 8	0.003	22.75	0.59057	0.135909
Coan 9	0.005	8.5	0.535908	0.244425
Coan 10	0.003	30.5	0.608821	0.22919
Coan 11	0.005	14.25	0.634975	0.301517
Coan 12	0.003	13.75	0.635119	0.153244
Coan 13	0.003	23.5	0.536554	0.198275
Coan 14	0.003	14.75	0.50396	0.179809
Coan 15	0.003	9.75	0.474107	0.071291
Coan 16	0.000	11.25	0.524394	0.173457
Coan 17	0.003	14.5	0.497744	0.007822

Table 10. Little Wicomico River, June 2003, Phosphate, Total Suspended Solids (TSS), Nitrate, and Ammonium.

Sample ID	Phosphate (mg/L)	TSS (mg/L)	Nitrate (mg/L)	Ammonium (mg/L)
CZM 6-20-03 1	0.005	18.75	0.22309	0.318525
CZM 6-20-03 2	0.008	22.75	0.198746	0.195348
CZM 6-20-03 3	0.005	16.5	0.203219	0.227849
CZM 6-20-03 4	0.005	15.25	0.224164	0.157221
CZM 6-20-03 5	0.000	17.0	0.219119	0.198667
CZM 6-20-03 6	0.000	24.25	0.007518	0.254513
CZM 6-20-03 7	0.000	10.25	0.210188	0.302293
CZM 6-20-03 8	0.000	9.75	0.008228	0.174027
CZM 6-20-03 9	0.000	7.25	0.011199	0.115129
CZM 6-20-03 10	0.005	11.25	0.005703	0.338868

Table 11. Piankatank River, March 2003, Nitrate, Ammonium, Phosphate, and Total Suspended Solids.

Lab #	NO3-N mg/l	NH4-N mg/l	PO4 mg/l	TSS mg/l
1	0.126345	0.009504	0.000	11
2	0.142137	0.048076	0.005	9.25
3	0.171394	0.103869	0.000	10.25
4	0.136614	0.021028	0.000	11.5
5	0.112211	0.084349	0.000	9.75
6	0.085287	0.024941	0.000	9.75
7	0.17754	0.136855	0.000	14.75
8	0.099169	0.101542	0.000	7
9	0.10593	0.023463	0.000	11.5
10	0.126438	0.082172	0.000	7.5
11	0.088577	0.113835	0.000	7.25
12	0.012542	0.088971	0.000	9
13	0.135438	0.106014	0.000	8.75
14	0.086585	0.026021	0.000	11
15	0.127226	0.071747	0.000	15.25

Image 1. The fluorometer set up for continuous flow in the field. A submersible pump on the end of an extended hose pumps water through the detector and back out through an exit hose.

Image 2. Division of Shellfish Sanitation (VDH) boat used to tow a Jon boat to areas where the fluorometer was tested.

Image 3. Jon boat set up to use the fluorometer. The submersible pump is located on the end of the pvc pipe and water flows through a hose inside the pvc pipe, then through the fluorometer.

Image 4. Typical older home where some type of on-site system is between the house and the bulkhead, and shellfish-bearing waters are closed to harvest due to fecal bacteria.

Image 5. Typical older marina located in a secluded cove, and served by a pit privy. Shellfish bearing waters in the cove are closed to harvest due to fecal bacteria.